

**A Basic Comparison
of the Space Shuttle Main Engine
and the J-2X Engine**

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Abstract

With the introduction of the new manned space effort through the Constellation Program, there is an interest to have a basic comparison of the current Space Shuttle Main Engine (SSME) to the J-2X engine used for the second stage of both the Ares I and Ares V rockets. This paper seeks to compare size, weight and thrust capabilities while drawing simple conclusions on differences between the two engines.

Introduction

Space flight in the United States is in the process of changing. The Space Shuttle Program is coming to a close only to be replaced by a new initiative in space exploration with the program Constellation. This new program will separate the current Space Shuttle's functionality into two vehicles – one for crew and the second for cargo.

The Marshall Space Flight Center (MSFC) Resident Office is the eyes and ears of the MSFC at the Kennedy Space Center (KSC). The MSFC Resident Office oversees the implementation of propulsion engineering mandates handed down from the home center in Huntsville, Alabama. MSFC provides project management and oversees design aspects of propulsion elements for both the Space Shuttle and Constellation Programs.

With the start of the new program there is need to understand the difference between the old and the new as all of the involved NASA Centers will need to determine how to allot resources, processing times and so forth for Constellation operations. Of specific interest in this area is the comparison of the current SSME with the second stage engine, J-2X, slated for use with the new rockets, Ares I and Ares V. This paper makes basic comparisons of the current SSME and the new second/upper stage engine, J-2X.

Space Shuttle Main Engine

The SSME is the work horse of the shuttle program. Measuring 14 feet (4.2 meters) long and 7.5 feet (2.25 meters) in diameter at the nozzle end, just the sheer size of the SSME is impressive in and of itself.

Weighing 7,000 pounds (3,150 kilograms) the SSME easily boasts 470,000 pounds of vacuum thrust. During the approximately 8.5 minutes of operation during take-off and ascent the three SSMEs burn more than 500,000 gallons (1.9 million liters) of liquid hydrogen and liquid oxygen propellant. These propellants are stored in the large expendable external tank attached to the underside of the Space Shuttle Orbiter.

There are three SSMEs mounted on each Orbiter Vehicle. The SSME is the world's most sophisticated reusable



Figure 1 - Space Shuttle Main Engine (NASA)

rocket engine. Such a complex machine requires many hours of detailed maintenance and inspection between flights to keep the engine flight worthy. This intricate maintenance, such as removing residual byproducts after space flight, occurs at the KSC Engine Shop located in the Launch Complex 39 Area. The engine shop performs work on the SSME while located in both horizontal and vertical positions. Initial post/pre-flight, off-orbiter inspections are completed with the engine in a horizontal position following removal from and prior to installation in the Space Shuttle Orbiter Vehicle. Operations in this horizontal position include gaseous purges, leak check and other preliminary inspections.

To access the main functioning elements of the engine, each SSME will be rotated over from horizontal to vertical and placed in a vertical stand where technicians have ease of access during all remaining work. After each flight, when in this vertical position, hardware is inspected then removed and replaced as necessary. Most parts of the SSME are handled in-house at KSC.

Before installation in the Orbiter Vehicle, all SSMEs for the current flight sequence receive flight readiness certification and are rotated back to horizontal. After transfer to the Orbiter Processing Facility the SSMEs will be installed and initial close-outs performed. However, the final vertical flight form of the engine will not be realized until after Orbiter Mate.

Overall, the SSME is a sophisticated reusable rocket engine which requires much care through many hours of inspections and re-furbishing operations between each subsequent flight. The SSME does however use technologies that are no longer available and would require significant updating before construction of additional engines could occur.

J-2X

For the second stage of both the Ares I and Ares V Constellation Project rockets, an engine similar to the Space Shuttle Main Engine has been selected. The J-2X is once again a liquid fueled rocket engine using hydrogen and oxygen as the fuel and oxidizer respectively. The base design of this engine uses legacy hardware from the Apollo era J-2 engine which powered the Saturn IB and Saturn V rockets, and hardware from the 1970's tested J-2S engine which never saw flight. With a vision to develop a single, highly reliable, and affordable engine satisfying requirements for the upper-stage engine of Ares I and the earth departure stage of the Ares V, the J-2X engine allows realization of this goal within the allocated time, budget and with acceptable risk.

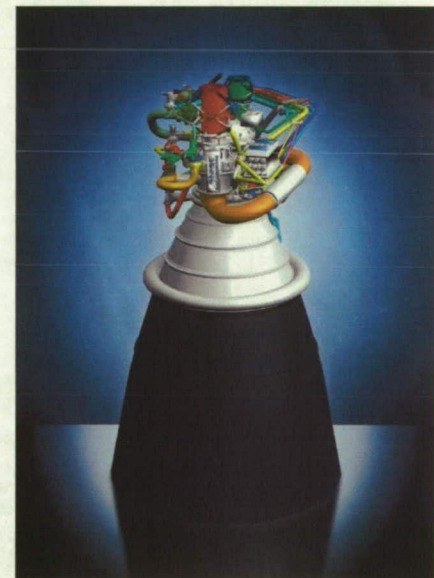


Figure 2 - Artist Concept of J-2X Engine 7.16.2007 (NASA)

The J-2X engine will measure 185 inches (4.7 meters) long and 120 inches (3.04 meters) in diameter at the nozzle end. It is slated to weigh in at 5,300 pounds (2,385 kilograms) producing a mere 294,000 pounds of thrust. However, this thrust will allow the J-2X to easily place the Orion crew exploration vehicle in low-earth orbit when used on the Ares I rocket.

J-2X and the Ares I

When used as the upper stage engine for the Ares I rocket the J-2X will deliver the Orion spacecraft, along with four to six astronauts, into low-earth orbit. For use in this configuration the J-2X will ignite approximately 133 seconds after liftoff. The ignition of the Ares I upper stage occurs at an altitude of about 191,000 feet (36 miles) following separation of the five segmented first stage solid rocket booster which is based on the current Solid Rocket Boosters used for the Space Shuttle Program.

During the J-2X's 465 seconds of Ares I operation the engine will consume more than 102,600 gallons (302,200 pounds) of propellant. Upon engine cutoff the Ares I upper stage will be at an altitude of 439,700 feet (83 miles) where it will separate from the Orion capsule. Shortly after Orion's engine will ignite to insert the capsule into low-earth orbit and rendezvous with either the International Space Station or the Earth departure stage of the Ares V rocket for lunar missions. The separated Ares I upper stage will return to earth and splash down in the Indian Ocean. Neither the J-2X nor the Ares I upper stage will be reused for subsequent missions.



Figure 3 - Concept image of launch of Ares I (NASA/MSFC)

Unlike the sophisticated reusable rocket engine that is the SSME, the expendability of the J-2X makes it desirable to remove all KSC related J-2X engine operations thus making it a "ship and shoot" component. To realize this idea proposals have been made to attach the J-2X to its propellant tank prior to shipment. Thus, upon arrival to Kennedy all operations would follow a track similar to the Space Shuttle's external tank.

J-2X and the Ares V

When used as the Earth departure stage of the Ares V rocket the J-2X will ignite twice. The initial ignition will place payloads into orbit around the earth for rendezvous with the Orion capsule of the Ares I rocket. The second, post-rendezvous ignition will allow the mated vehicle, now carrying explorers and hardware, to exit earth's orbit for travel to the moon.

More specifically, the J-2X in the Ares V configuration will first ignite approximately 327 seconds after liftoff. This event will occur at an altitude of approximately 347,800 feet (65.9 miles) following separation of the Ares V first stage. During this burn the J-2X engine will power for about 442 seconds consuming more than 101,000 gallons (290,000 pounds) of liquid hydrogen and liquid oxygen propellant.

For the Ares V, the second ignition of the J-2X engine occurs after establishing a steady low-earth orbit and the subsequent rendezvous with and mating of the Orion spacecraft delivered by an Ares I rocket. This final burn lasts around 319 seconds to accelerate the mated vehicles to "escape velocity." This is the speed required to break free from Earth's gravity. The earth

departure stage will then separate to orbit the sun while the mated Orion spacecraft will then travel to the moon. The Earth departure stage will not be reused in subsequent flights.

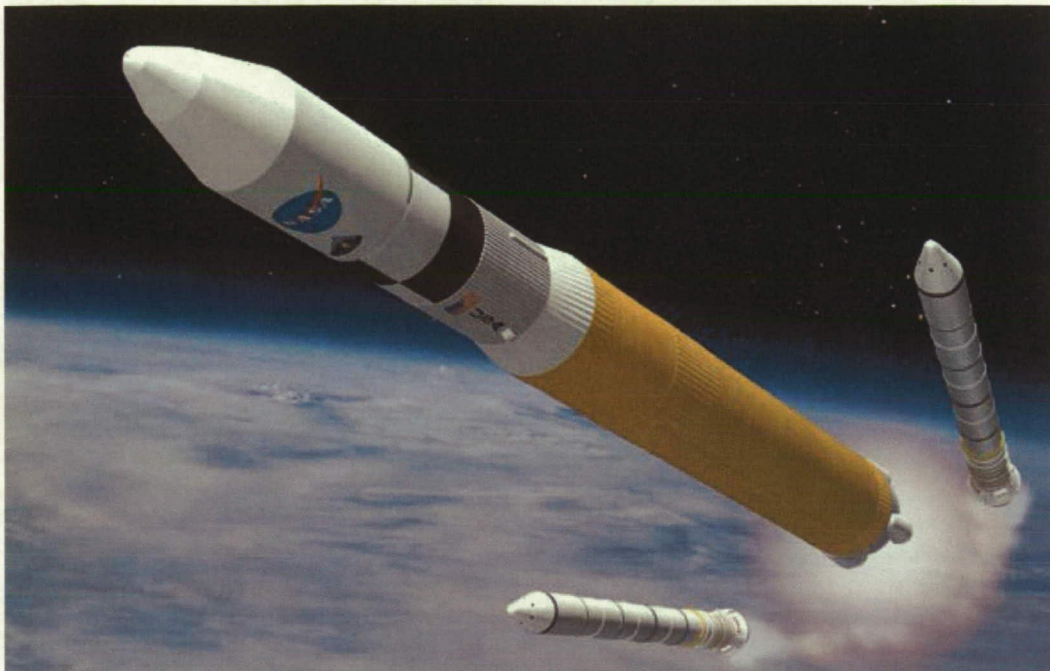


Figure 4 - Concept Image of Ares V in Earth orbit (NASA/MSFC)

Comparison

The J-2X engine for the Ares I and Ares V rocket will be larger than the SSME both in length and nozzle diameter. However, the J-2X will be nearly 2,000 pounds lighter than the SSME. The 294,000 pounds of thrust produced by the J-2X is not impressive as the 470,000 pounds of thrust produced by each SSME. The reduced thrust of the J-2X in comparison to the SSME, however, does not harm the J-2X's effectiveness in its role as a second-stage engine. With Ares I, the J-2X engine is used strictly for propelling the Orion crew module after separation of the first-stage solid rocket booster. For Ares V rockets the J-2X will ignite twice during each mission – first for low-earth orbit insertion and second to accelerate the vehicle to “escape velocity” for lunar missions.

The second ignition capability of the J-2X engine varies greatly from that of the SSME which ignites prior to liftoff then burns until Main Engine Cutoff without the possibility of re-ignition. The capability of the J-2X second ignition is required for the burn which accelerates the mated vehicle into orbit post rendezvous.

Out of necessity, mounting of the J-2X will vary greatly from the SSME. In both its Ares I and Ares V configuration the stage containing the J-2X engine is expendable. For Ares I the upper stage will splash down in the Indian Ocean; while the Earth departure stage of the Ares V will jettison to orbit around the sun after separation from the mated Orion spacecraft. There is no need for the J-2X engine to mount as part of a returnable module as required for the SSME, this allows for in-line, direct coupling of the engine to the propellant tank and thus minimal vehicle integration operations at KSC.

Conclusion

Though many people may try and directly compare the new J-2X engine with the current Space Shuttle Main Engine it should be noted that there are strict differences in functionality and requirements between the two engines. The SSME is the most sophisticated reusable rocket engine produced to date. The J-2X is an expendable rocket engine. In making comparisons between the two engines it must always be kept in mind that one is comparing reusable and expendable hardware. This causes large differences in the total time invested in each engine. However, inspections are and will remain strict and thorough for both engines. Specific comparisons of process can not yet be made as the proposed processing of the J-2X has yet to be released.

Even with the disconnects one may easily conclude that each engine seeks to serve its mandate. Both engines are liquid fueled engines using liquid hydrogen and liquid oxygen for propellant. Handling of the SSME is more extensive as each engine is constantly being reworked and recertified for flight. The J-2X however will see intensive processing prior to its one flight life. Overall, each engine has a separate purpose, seeks to fulfill that purpose and accomplishes this within schedule restraints, within budget and with acceptable risks.

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